Inflatable Module Inspection Needs

Workshop Session 5-4

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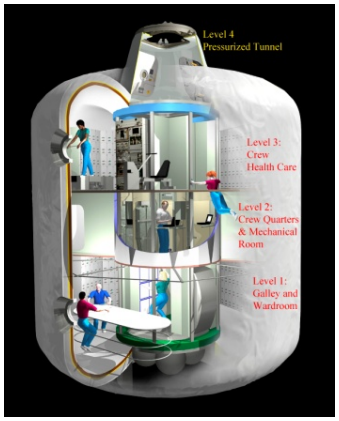
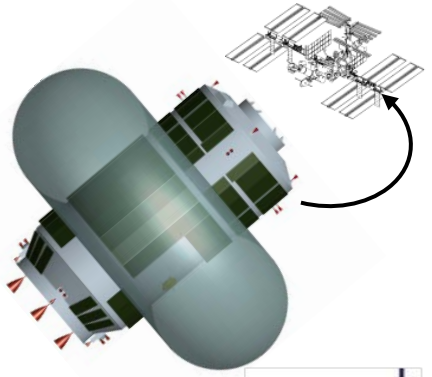
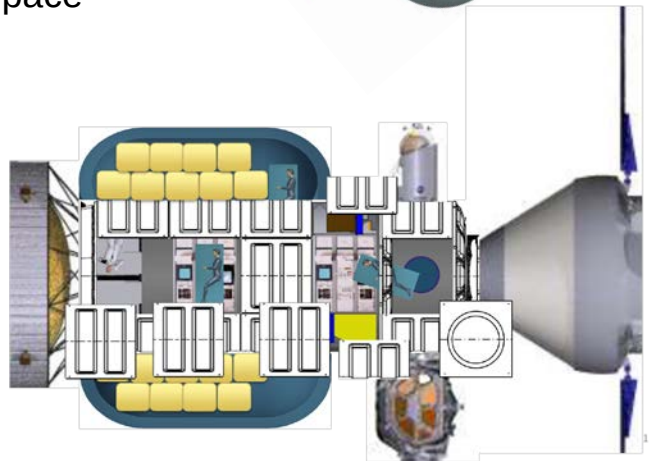
Inflatable Module Inspection Needs





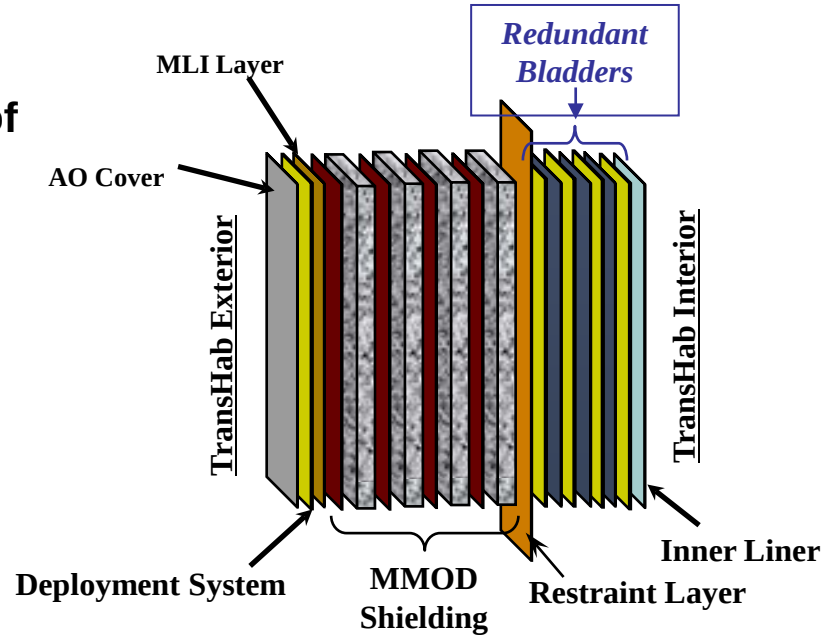


Inflatable Structures- Offer mass and volume benefits over traditional space structures

- TransHab
  - Originally designed for Mars transit
  - 25-ft diameter x 3 stories high
  - Morphed into ISS Design
- Bigelow Aerospace
  - Launched two expandable modules (Genesis I, 2006) and (Genesis II, 2007).
  - Sub-scale modules
  - Currently perusing putting an expandable module on ISS (BEAM)
- Flagship
  - Technology Demonstration on ISS in support of an eventual Deep Space Mission
- Deep Space Habitat
  - Deep Space Mission with potential early mission to EM L1/L2 or an asteroid
  - Inflatable Structures are in the trade space
  - Inflatable airlocks and tunnels have similar NDE needs at habitats

Inflatable Module Shell Layers

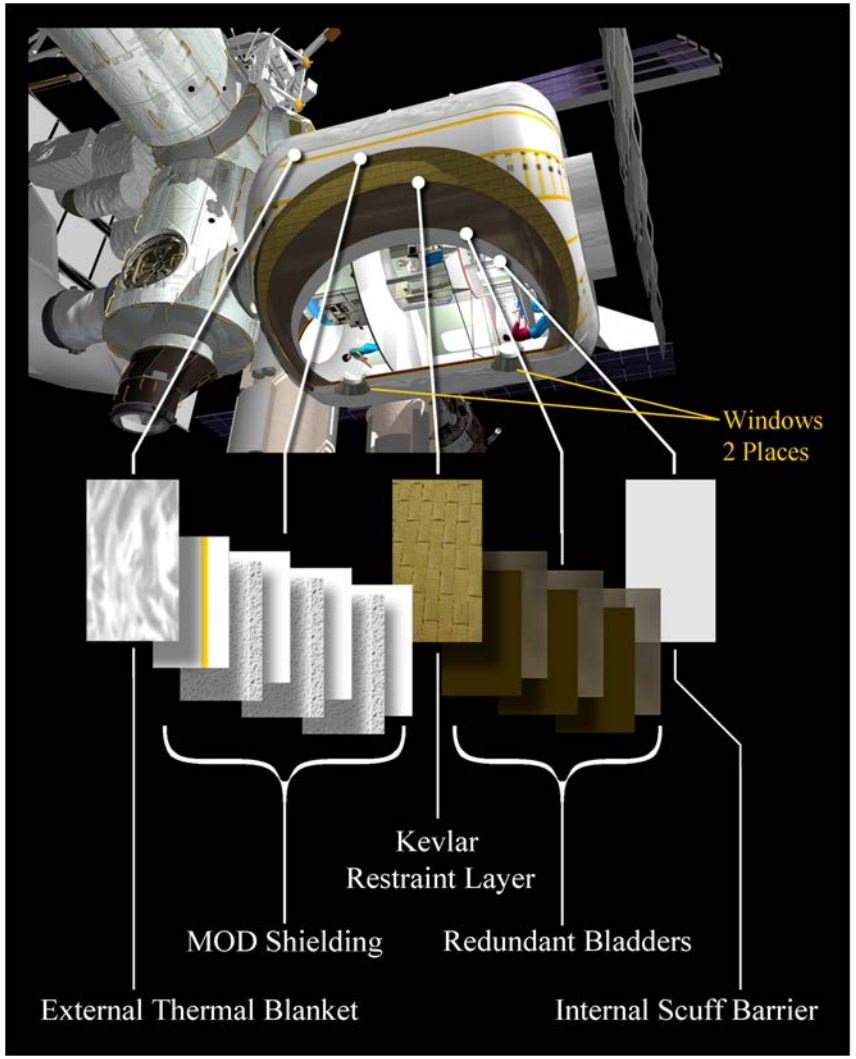
- **Typical Inflatable Module Layer**
  - **Inner Liner- Flame Resistant, puncture resistant (typical materials Nomex, Kevlar felt). May have to be removed to perform a through inspection of the bladder.**
  - **Bladder- Able to flex at cold temperature, low permeability, single or multi-layered, oversized, able to manufacture (seam). Some low permeable layers have a metalized layer which may cause inspection challenges. Seeing through metalized layers is beneficial.**
  - **Restraint Layer- Carries the structural load due to pressure. Typical Vectran or Kevlar. Desirable to detect damage to the structural restraint layer (real time and post damage identification and location).**



  - **Micrometeoroid Orbital Debris Layer- Multiple layers of debris shields. Typical ceramic fabric layers with Kevlar sheets as rear-wall. More efficient with standoff between layers. May be separated by cored out open cell foam possibly in vacuum packed bags. Orbital debris protection required for LEO drives shield size and mass. It is desirable to be able to detect on-orbit damage to the MM/OD layers (real time, post damage identification and location, depth of damage).**

Inflatable Module Shell Layers

- **Typical Inflatable Module Layer (cont.)**
  - **Multi Layered Insulation- Helps minimize large thermal gradients. Typical multiple layers of aluminized Kapton, aluminized Beta cloth. Desirable to determine thermal performance, identify and locate damage. Seeing through metalized layers is desirable.**
  - **Deployment System- Wraps folded layers in stowed configuration. Supports launch ascent loads.**
  - **Atomic Oxygen Protective Layer- Required for low earth orbit (LEO). Typical Beta-cloth fabric. Desirable to identify and locate damage.**



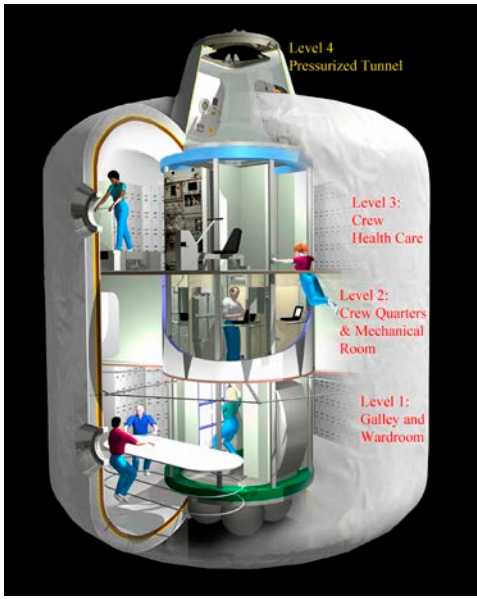
*** Adding doping components to the fabric materials may benefit NDE inspection**

Inflatable Module Inspection Needs

- Inflatable Structure Inspection Needs
  - Prelaunch packaged state
    - None planned (nominal)
  - Launch/Ascent
    - External video (optional: measure billowing?)
  - Vehicle extraction
    - External video
  - On-orbit before deployment
    - Thermal imaging (optional)
  - Post Deployment (Validation of initial deployment)
    - Leak detection/location
    - Thermal imaging

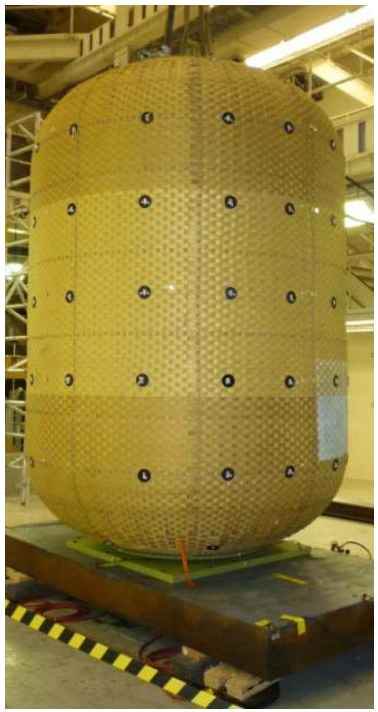
Inflatable Module Inspection Needs

- Inflatable Structure Inspection Needs (cont.)
  - On-orbit operations
    - Leak detection
      - acoustic emissions
      - external gas emitting sensors
      - video
    - Structural damage sensors (autonomous and crew supported)
      - impact detection sensors
      - thermal imaging
      - penetrating 3-D Imagers
      - serpentine imaging robots (w/ inner liner removal)
      - external camera inspection (fixed, translating, and free flyers)



Inflatable Module Inspection Opportunities

- Development Testing - Possible opportunities to include NDE sensors for some tests
  - Modal Testing (performed 12/2011)
    - WLE, DIDS, and Acoustic Emission, sensors were installed internal/external an inflatable test article
  - Micrometeoroid/Orbital Debris Hypervelocity testing
    - Impact detection (at impact)
    - Impact location methods
  - Leak Testing (at operational pressure) – (FY12+)
    - Leak detection/location
  - Damage Tolerance Testing (DTT) – (FY12+)
    - Impact detection when damage imparted
    - Damage inspection methods



Inflatable Module Inspection Opportunities

- Development Testing (cont.)
  - Burst Testing
    - Impact testing at operational pressure
    - Fabric strain measurement methods (currently using strain gages mounted onto clevises and photogrammetry)
  - Thermal Vacuum Testing (sub-scale)
    - Thermal imaging in the folded and deployed states
  - Thermal Vacuum Testing (full scale)
    - Thermal imaging in the folded and deployed states
  - Rapid Depress/Ascent Testing (sub-scale)
    - Thermal imaging in the folded and deployed states
    - Video imaging to detect damage
    - X-ray imaging to detect damage